RP 508 Oil Analysis Data Collection and Reporting Procedures

The following recommended practice (RP) is subject to the disclaimer at the front of this manual. It is important that users read the disclaimer before considering adoption of any portion of this recommended practice.

This recommended practice was prepared by a committee of the AWEA Operations and Maintenance (O&M) Committee.

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Purpose and Scope

The scope of "Oil Analysis Data Collection and Reporting Procedures" describes best practices in oil analysis data collection and reporting procedures for optimal information on the condition of the monitored component and proper maintenance actions.

Introduction

Experience has shown that premature gearbox failures are a leading maintenance cost driver of wind turbine operation. Premature gearbox failures reduce turbine availability, result in lost production and downtime, and can add significantly to project lifecycle cost of operation. Oil debris and oil condition monitoring, used in conjunction with prognostics and health management (PHM) monitoring to assess and monitor the health of a wind turbine gearbox, should be part of a comprehensive condition monitoring program.

Oil debris and oil condition analysis techniques offer the potential for detecting early component damage and lubricant degradation, trending the severity of such damage, estimating the time to reach pre-defined damage limits, and providing key information for proactive maintenance decisions, often prior to other monitoring techniques.

Oil debris RP 818 "Wind Turbine On-line Gearbox Debris Condition Monitoring" and oil condition RP 819 "Online Oil Condition Monitoring" monitoring can be accomplished through continuous online sensors or traditional offline "point-in-time" oil and grease RP 815 "Wind Turbine Grease Analysis Test Methods" analysis sampling[1].

Data Collection

Data collection methods for offline periodic monitoring and online continuous monitoring are summarized below.

1. Offline Periodic Monitoring

Offline periodic “point-in-time” oil, grease, and filter samples, typically taken every six months for wind turbines, are sent to a laboratory for analysis. The laboratory analysis provides details on the oil’s physical properties and contaminants utilizing a wide variety of laboratory tests and instruments. The data generated from all these instruments should be automatically transferred to a laboratory information management system (LIMS) which also contains the sample collection and machinery component information. Manual transcription of data should be avoided.

2. Online Continuous Monitoring

Online sensors provide continuous monitoring for each component being monitored at regular intervals, for example daily. This near real-time data is exported automatically by a variety of methods, such as general packet radio service (GPRS) cellular modem, supervisory control and data acquisition (SCADA), or Ethernet, to a central monitoring location where the data is automatically processed to assess the health of the component.

Data Variability

Oil analysis data is impacted by a wide variety of factors which need to be taken into account for repeatable and reproducible oil analysis data interpretation[2].

1. Operational and Maintenance Actions

Operational and maintenance actions impact data in predictable ways and these actions should be provided with each sample.

1.1. Operational intensity can impact how quickly a component wears and how rapidly a fault progresses. A relevant indicator of machine usage should be included in any limit and trend calculations.

1.2. Sampling, maintenance, filter, and oil changes are rarely performed at precise intervals. These irregular, opportunistic intervals have a profound effect on measurement data and interfere with trending techniques. Consequently, they need to be taken into account for accurate limit and trend calculations.

2. Sample Collection Techniques

Proper sample collection techniques play a large role in providing representative data. The recommended procedures in RP 102 “Wind Turbine Gearbox Oil Sampling Procedure” and RP 815 “Wind Turbine Grease Analysis Test Methods” should be followed.

3. Laboratories and Test Instruments

Laboratories and test instruments also impact data. This section provides examples of factors that impact oil analysis data interpretation. Online sensors have the benefit of overcoming some of these factors. The following should be adhered to for improved repeatability and reproducibility of data:

3.1. Variations in laboratory analytical instruments impact data reliability. Ideally, trending should only be performed on results obtained from the same make and model of test instrument.

3.2. If samples are analyzed at more than one laboratory, the laboratories should be in a quality assurance program demonstrating a correlation in results obtained from each laboratory and each instrument.

3.3. Laboratories utilized should be certified to ISO 17025[3] to enhance confidence in the results.

Data Analysis

A significant amount of data is generated by oil analysis monitoring. This data needs to be reduced to useful information regarding component health. Level limits are established to indicate different stages of a fault in progress. Finite limits are typically utilized for parameters, such as allowable water contamination[4]. However, in addition to level limits, trending the rate of progression of a failure is also very important. A significant change in trend is indicative of the rate of damage progression towards level limits of defined failure stages[5]. Identifying a failure in the early stages is much more cost effective than allowing it to progress to later failure stages of the machine. Condition monitoring information should clearly and consistently indicate machinery condition from normal through various stages of failure.

Results Reports

Reports for offline periodic monitoring are obtained from oil sample analysis laboratories and reports for online continuous monitoring from automated data processing algorithms.

1. Laboratory Analysis Results

Laboratory analysis results of an oil, grease, or filter sample provide a detailed report of a lubricant's physical properties and quantitative analysis of key contaminants. Figure A is a typical report that provides:

- Customer information
- Component information
- Sample information
- Current sample data
- Two or more prior samples of data for comparison
- New oil data for comparison
- Limit values, if available, for each applicable parameter measured
- Trend values or trend charts, if available, for each applicable parameter measured
- Laboratory comments
- Laboratory recommendations

Limits utilized in the report should state if they were derived based on customers' historical data specific to their components or if they are generic to machine and oil type.

Note that not all parameters measured are applicable to the component. Thus, for non-relevant parameters, level limits and trends are not assigned. Numerous laboratory tests are available. Not all of them provide useful information on component health or can be linked to a failure mode.

1. Laboratory Analysis Results
(continued)

Machine Condition	NORMAL
Lubricant Condition	MARGINAL

Machine Name: WT1 GEARBOX

Analysis Report

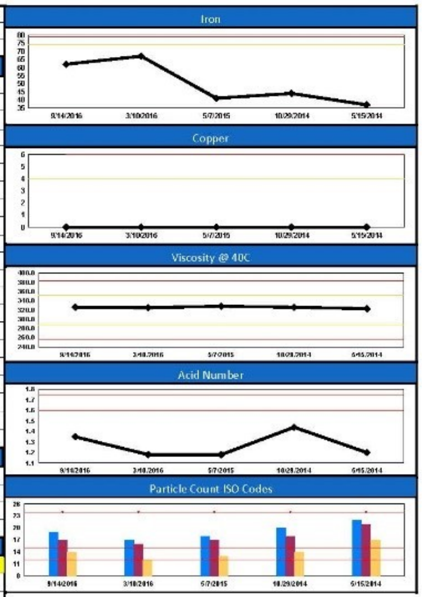
Component Information		Sample Information		Customer Information
Machine Type: Industrial Gear	Sump Size: Unknown	Received:	09/15/2016	Wind Farm X
Lubricant:		Report:	09/15/2016	
Machine MFG:				
Machine MOD:				

PROBLEMS
Excessive Particle Count

COMMENTS The particulate contamination exceeds our limits for a gearbox (24/15/12). High particulate contamination will lead to abrasive wear and damage internal components. Reducing particle levels will significantly extend component life.

CUSTOMER NOTES

	Date Sampled	NEW OIL	9/14/2016	3/10/2016	5/7/2015	10/29/2014	5/15/2014
	Lab No	1708048	1776399	1653045	1512386	1372947	1317348
	Machine / Lube Cond.		N / M	M / M	N / M	N / M	N / M
ELEMENTAL SPECTROSCOPY (ppm) ASTM D5185 Mod (-) indicates below detection limit							
Wear Metals	Iron	-	62	67	41	44	37
	Copper	-	-	-	-	-	-
	Lead	-	-	-	-	-	-
	Aluminum	-	-	-	-	-	-
	Tin	-	-	-	-	-	-
	Nickel	-	-	-	-	-	-
	Chromium	-	-	-	-	-	-
	Titanium	-	-	-	-	-	-
	Vanadium	-	-	-	-	-	-
	Silver	-	-	-	-	-	-
Additives	Calcium	-	-	-	-	-	-
	Magnesium	-	20	29	18	7	33
	Phosphorus	489	411	540	335	412	494
	Zinc	-	31	36	24	9	32
	Barium	-	-	-	-	-	-
	Molybdenum	-	37	45	34	20	95
Contaminants	Silicon	-	-	-	-	-	-
	Boron	49	31	37	35	30	44
	Lithium	-	-	-	-	-	-
	Sodium	-	8	11	-	-	-
	Potassium	-	-	-	-	-	-
FTIR SPECTROSCOPY (Indexing Numbers) ASTM E2412							
	Oxidation	60	59	54	56	59	54
	Nitration	1	2	1	2	1	1
	Anti Wear	15	15	15	15	16	14
	Other Fluid	52	52	52	54	54	51
PARTICLE COUNT (particles per ml) ISO 4406:99							
	ISO Code	18/16/13	19/17/14	17/16/12	18/17/13	20/18/14	22/21/17
	>4 Micron	1446	3264	1008	2178	5103	38670
	>6 Micron	561	1269	392	847	1984	15039
	>14 Micron	43	96	29	63	151	1147
	>50 Micron	1	4	1	2	6	50
	>100 Micron	0	0	0	0	0	2
VISCOSITY (centistokes) ASTM D445							
	Viscosity@40°C	327.8	326.2	325.4	328.2	326.4	323.3
ACID NUMBER (mg KOH/g) ASTM D974							
	Acid Number	0.88	1.35	1.18	1.18	1.44	1.20
WATER (PPM) a-ASTM D6304A b-IWI-133 c-ASTM D6304C d-IWI-134* e-IWI-135* f-IWI-136* g-Crackle h-IWI-370*							
	Water		100 (c)	134 (c)	140 (c)	40 (c)	100 (c)



Testing performed by Lab X, an ISO/IEC 17025:2005 accredited laboratory. L-A-B Accredited Certificate Number xxxx Testing. (*) - Not in scope of accreditation. Wind Farm X assumes sole responsibility for the application of and reliance upon results and recommendations reported by Lab X, whose obligation is limited to good faith performance.

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Lab No. 1776399

Figure A: Laboratory Oil Analysis Report

2. Online Sensor Data

Online sensor data processing provides automated analysis of near real-time results for the parameters they are measuring, such as wear debris. Figure B is a typical daily sensor report for each sensor that indicates the status of each component by means of a trend plot identifying normal or alarm conditions with details on rate of damage progression for the failure mode. Figure C is a typical report that provides the status of all monitored components for the entire wind farm(s). Due to increased time reporting granularity, the real-time online sensor data provides earlier indication of a component's health status, thus allowing operators to identify and take corrective action sooner to improve long-term reliability and reduce lifecycle cost.

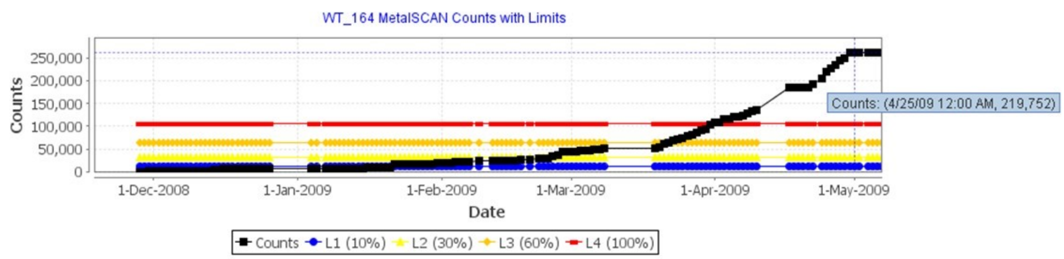
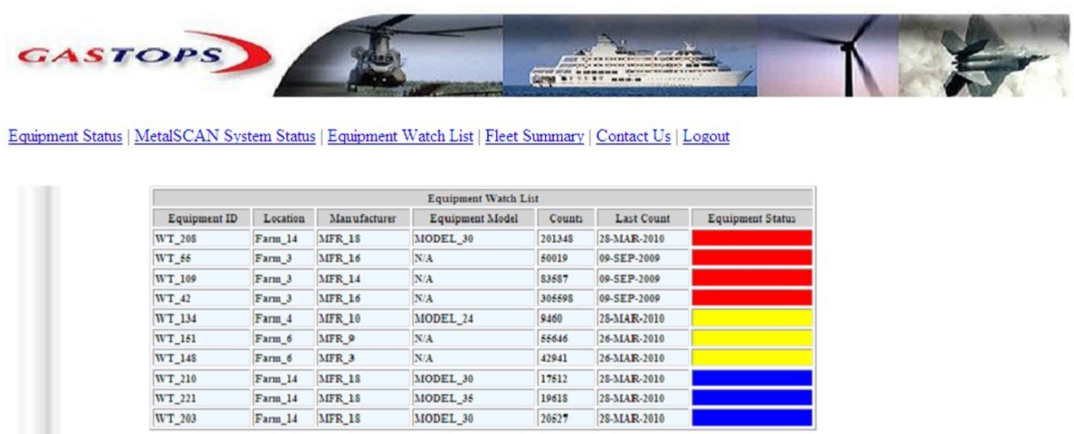


Figure B: Online Wear Debris Sensor Report. Trend Plot with Limits for One Gearbox.



Equipment Watch List

Equipment ID	Location	Manufacturer	Equipment Model	Counts	Last Count	Equipment Status
WT_208	Farm_14	MFR_18	MODEL_30	201348	28-MAR-2010	
WT_55	Farm_3	MFR_16	N/A	50019	09-SEP-2009	
WT_109	Farm_3	MFR_14	N/A	83587	09-SEP-2009	
WT_42	Farm_3	MFR_16	N/A	305598	09-SEP-2009	
WT_134	Farm_4	MFR_10	MODEL_24	9460	28-MAR-2010	
WT_151	Farm_6	MFR_9	N/A	55646	26-MAR-2010	
WT_148	Farm_6	MFR_3	N/A	42941	26-MAR-2010	
WT_210	Farm_14	MFR_18	MODEL_30	17512	28-MAR-2010	
WT_221	Farm_14	MFR_18	MODEL_35	19618	28-MAR-2010	
WT_203	Farm_14	MFR_18	MODEL_30	20527	28-MAR-2010	

Figure C: Online Wear Debris Sensor Report. Wind Farms by Over Limit Status.

Results Integration

Oil and wear debris analysis results should be integrated with results from other sources of information that include condition monitoring results whenever possible, such as vibration and performance condition indicators. Systems can be configured to integrate various types of condition monitoring data, system configuration data, operational data, and maintenance data from different databases to provide enhanced diagnostics and prognostics information.

Summary

Maintaining proper lubrication and early detection of oil wetted component failures is critical to maximize component life and reduce lifecycle costs of a wind turbine. Oil debris and oil condition monitoring are effective techniques to support this goal. Analysis of the significant amount of data for useful information is provided through offline laboratory or online sensor data processing and reporting tools.

References

[1] *Standard Practice for Inductive Wear Debris Sensors in Gearbox and Drivetrain Applications*, ASTM D7917-14, 2014

[2] L. A. Toms, and A. M. Toms, *Machinery Oil Analysis -- Methods, Automation and Benefits*, 3rd ed., Park Ridge, IL: STLE, 2008, ch. 9.

[3] *General Requirements for the Competence of Testing and Calibration Laboratories*, ISO/IEC 17025:2005, 2005.

[4] *Standard Guide for Statistically Evaluating Measurand Alarm Limits when Using Oil Analysis to Monitor Equipment and Oil for Fitness and Contamination*, ASTM D7720-11, 2017.

[5] *Standard Guide for Practical Lubricant Condition Data Trend Analysis*, ASTM D7669-15, 2015.